

Computer Science 271
Project 0011
Due Wednesday, February 15

Type your answers in *L^AT_EX*.

1. Where in a min-heap might the largest element reside, assuming that all elements are distinct?
2. Is an array in sorted order a min-heap? Why or why not?
3. Implement a `MinHeap` template class, and the heap sort algorithm. The heap sort method should return a copy of the array in *ascending* sorted order. The class definition follows.

```
template <class KeyType>
class MinHeap
{
public:
    MinHeap(int n = DEFAULT_SIZE);           // default constructor
    MinHeap(KeyType initA[], int n);         // construct heap from array
    MinHeap(const MinHeap<KeyType>& heap);    // copy constructor
    ~MinHeap();                             // destructor

    void heapSort(KeyType sorted[]);         // heapsort, return result in sorted
    std::string toString() const;           // return string representation
    MinHeap<KeyType>& operator=(const MinHeap<KeyType>& heap); // assignment operator

private:
    KeyType *A;                             // array containing the heap
    int heapSize;                           // size of the heap
    int capacity;                           // size of A

    void heapify(int index);                 // heapify subheap rooted at index
    void buildHeap();                       // build heap

    int leftChild(int index) { return 2 * index + 1; } // return index of left child
    int rightChild(int index) { return 2 * index + 2; } // return index of right child
    int parent(int index) { return (index - 1) / 2; } // return index of parent

    void swap(int index1, int index2);       // swap elements in A
    void copy(const MinHeap<KeyType>& heap);  // copy heap to this heap
    void destroy();                         // deallocate heap
};
```

A copy of this header file is available in the directory `/share/havill/271/proj3/`.

Notes:

- The second constructor should dynamically allocate `A`, copy the contents of `initA` to `A`, and then call `buildHeap`. (Therefore, `heapSort` need not call `buildHeap`.)

- The `heapSort` method should return the sorted array *in ascending order* in the parameter named `sorted`. It is the responsibility of the caller to allocate `sorted` to be large enough to hold the result.
 - Include suitable preconditions and postconditions in the comments before each method.
 - Include unit tests (using `assert` and the `toString` method) for each of your methods.
4. Plot the running time of heap sort for a variety of sufficiently large input sizes and compare this to the running time of the other sorting algorithms that you implemented in CS 173. The code below illustrates how you can time your sorting algorithms.

```
#include <sys/time.h>

int main()
{
    # set up stuff here

    timeval timeBefore, timeAfter;
    long diffSeconds, diffUSeconds;

    gettimeofday(&timeBefore, NULL);

    # call sort here

    gettimeofday(&timeAfter, NULL);

    diffSeconds = timeAfter.tv_sec - timeBefore.tv_sec;
    diffUSeconds = timeAfter.tv_usec - timeBefore.tv_usec;
    cout << diffSeconds + diffUSeconds/1000000.0 << " seconds" << endl;

    return 0;
}
```

5. What is the asymptotic time complexity of the heap sort algorithm on an array that is already sorted? What is the asymptotic time complexity on an array that is in reverse order? What is the best case asymptotic time complexity of heap sort, and on what kind of input does it occur?

To submit your project, please submit the following via Notebowl:

1. the following source files: `heap.cpp` and `test_heap.cpp`
2. and a **single** PDF named `proj3_yourname.pdf` that combines a PDF of the above source files (created using `enscript`) with your answers to the questions.

You can join together two PDF files using the `pdfjoin` program. If your source code PDF is named `proj3_yourname_code.pdf` and the PDF containing your answers to the questions is named `proj3_yourname_quest.pdf`, then join them together into a single PDF named `proj3_yourname.pdf` with

```
pdfjoin -o proj3_yourname.pdf proj3_yourname_code.pdf proj3_yourname_quest.pdf
```